CAN ONE PROBE THE STRUCTURE FUNCTION OF THE POMERON?

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ABSTRACT

We discuss whether the diffractive structure functions defined by current experiments at HERA are indeed probing the partonic structure function of the pomeron. We observe that the *pseudorapidity* cuts commonly employed require that the struck parton in the pomeron be far off mass shell in sizeable regions of parameter space. As a result an interpretation in terms of constituent partons within the pomeron is inadequate. One may nevertheless use a partonic description for the *amplitude* for virtual photon-pomeron scattering to compute a diffractive structure function for pseudorapidity gap events. The resulting form may have significant scaling violation.

1   Introduction

There has been intense interest in the interpretation of the large *pseudorapidity* gap events observed at HERA in deep-inelastic scattering processes [1, 2, 3, 4]. Such events must involve the exchange of a colourless state between the proton and the virtual photon, and, at high energies, the diffractive component corresponding to pomeron exchange will be dominant. Assuming that this component is responsible for the observed events, the data lead to the determination of a diffractive structure function. It has been suggested by Ingelman and Schlein [5] that such measurements should allow the distribution of quark and gluon partons within the pomeron to be determined, which would clearly be a very interesting possibility [6].

In this letter we consider the extent to which the current experiments at HERA address the Ingelman-Schlein proposal. We argue that the kinematics of experiments that use a strong cut in *pseudo*rapidity (i.e. $\eta = -ln(tan(\theta_{lab}/2))$) to define a diffractive structure function do not admit a simple interpretation in terms of the partonic structure of the pomeron, because the struck quark or gluon cannot always be close to its mass shell. However, we argue that, even with such a pseudorapidity cut, there is a valid description in which an off-shell parton emanates from the virtual photon and scatters diffractively off the proton[1] This should be evaluated by computing the full photon-pomeron scattering amplitude, thus retaining the coherence effects involved in having the struck parton far off mass shell. We present such a calculation, and show that the resulting cross section can be written in a factorised form, in which the diffractive structure function exhibits a modification of the usual scaling behaviour which are characteristic for the process.

The various experimental cuts used have differing sensitivity to the virtuality of the struck parton. For example the ZEUS Collaboration has recently published a new extraction of a diffractive structure function which does not involve a pseudorapidity cut, but makes an event selection based on the invariant mass of the hadronic system produced in association with unseen remnants of the proton [3]. Thus these experiments will have a component of varying importance which may be interpreted in terms of parton distributions within the pomeron, but all will also involve a significant component involving far-off-mass-shell partons.

2   Kinematics of Diffractive Deep-Inelastic Scattering

The experimental results [1, 2, 3, 4] are usually presented in a form analogous to that of the total deep-inelastic scattering cross section, namely

$$\frac{d^3\sigma_{diff}}{d\beta dQ^2 dx_{\mathcal{P}}} = \frac{2\pi\alpha^2}{\beta Q^4}(1 + (1-y)^2)F_2^{D(3)}(\beta, Q^2, x_{\mathcal{P}}) \tag{1}$$

where the contribution of F_L is neglected. The effect of neglecting F_L corresponds to a relative reduction of the cross section at small $x_{\mathcal{P}}$ (high W^2) which is always $< 17\%$ [1, 2, 3, 4],

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[1]A similar proposal has been made in different terms by Bjorken [7]. For a related discussion of the interpretation of the rapidity gap events in terms of a simple gluon structure function, see [8].

and therefore smaller than the typical present measurement uncertainties ($\simeq 20\%$).

The variables Q^2 and y have the definitions usual for deep-inelastic scattering. The variables $x_\mathcal{P}$ and β are defined as

$$x_\mathcal{P} = \frac{(P - P').q}{P.q} \simeq \frac{M^2 + Q^2}{W^2 + Q^2} \tag{2}$$

$$\beta = \frac{Q^2}{2(P - P').q} \simeq \frac{Q^2}{M^2 + Q^2} \tag{3}$$

where W^2 and M^2 are the total hadronic invariant mass squared and the mass squared of the hadrons excluding the proton remnants, respectively. In the framework of the underlying quark parton diagram of Fig. 1, these would normally be interpreted as the momentum fraction of the pomeron within the proton and the momentum fraction of the struck quark within the pomeron, respectively.
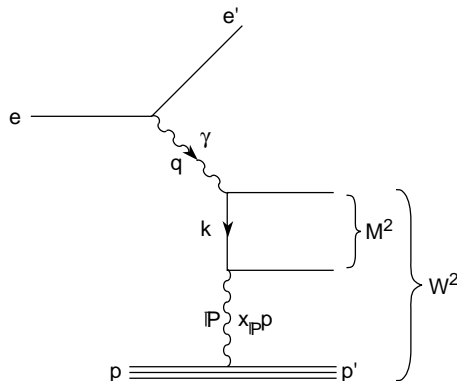

Figure 1: Quark-parton graph contributing to the large-rapidity-gap diffractive scattering amplitude.

We argue that the kinematics of the initial HERA experiments are such that one cannot in fact interpret the graph of Fig. 1 in terms of a conventional parton density within the pomeron. The reason is that, if one wants a probabilistic interpretation of Fig 1, with the cross section factorized as the product of an elementary subprocess cross section with the probability to find a parton within the pomeron viewed in the direct channel, the parton should be near its mass shell. On the other hand, in order to interpret the graph as a diffractive process, the sub-energy $(k + p)^2 \equiv s_{diff}$ should be large enough for the leading singularity in the cross channel, namely the pomeron, to be dominant, giving rise to an amplitude behaving as $s_{diff}^{\alpha_\mathcal{P} - 1}$, where $\alpha_\mathcal{P}$ is the intercept of the pomeron Regge trajectory. This leads to the $x_\mathcal{P}^{-(2\alpha_\mathcal{P} - 1)}$ dependence of the cross section which is indicated by experiment. The trouble with the partonic interpretation of these diffractive events arises because it requires that the parton has a longitudinal momentum equal to some fraction of that of the pomeron, $\beta P_\mathcal{P}$, which in turn carries only a small fraction of the proton momentum, $P_\mathcal{P} = x_\mathcal{P} P$. Thus, if the partonic interpretation applies, $k \approx \beta P_\mathcal{P} = \beta x_\mathcal{P} P$, and so $s_{diff} = (k + P)^2$ is small, in potential conflict with the requirement that the process be diffractive.

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Indeed, as discussed below, one finds that, for the strongest pseudo-rapidity cuts for a range of $x_{\mathcal{P}}$, β and Q^2, the dominant part of the cross section comes from $k^2 \sim Q^2$, rather than k^2 small and near mass shell. Thus the interpretation of Fig. 1 is not the standard one for deep-inelastic scattering off a hadronic target, but one in which the struck parton is far off shell. This means that the graph of Fig. 1 cannot be calculated as the product of two separate cross sections $\sigma_{q/\mathcal{P}}.\sigma_{\gamma q \to X}$, but must instead be considered as a complete amplitude $A_{\gamma\mathcal{P} \to \mathcal{X}}$. This also means that the interpretation of the analysis as a determination of the parton distribution within the pomeron needs re-evaluation.

3 Parton Virtuality in Diffractive Scattering

In order to quantify our claim that, at least for some of the experimental cuts, the dominant part of the diffractive cross section comes from a struck parton far off shell, let us consider Fig. 1 again in more detail. The condition that the final state quark is on-shell implies

$$k^2 = -2x_{\mathcal{P}}k.p = -x_{\mathcal{P}}s_{diff} \tag{4}$$

If this process is to be dominated by pomeron exchange, s_{diff} should be large. However, since $x_{\mathcal{P}}$ can be very small, this constraint does not by itself require that the struck parton be far off-mass-shell. Working in the photon-pomeron centre of mass frame, one readily determines that

$$k^2 = \frac{M_X^2 + Q^2}{2}(1 - \cos\theta_{cm}) \tag{5}$$

where θ_{cm} is the centre-of-mass angle between the proton direction and the final-state quark. Apart from the region $\cos\theta_{cm} \simeq 1$, the struck quark is clearly off mass shell.

The Ingelman-Schlein proposal applied to the quark constituents of the pomeron has been developed by Donnachie and Landshoff [6]. They argue that this process is indeed dominated by the region $\cos\theta_{cm} \simeq 1$, and that the quark-pomeron coupling has a form factor that falls rapidly for large k^2, so that $k^2 \leq 1 GeV^2$ gives the only significant contribution. They reach this conclusion by considering the inclusive diffractive cross section, i.e., including events which have no large rapidity gap. These events are expected to be given by the imaginary part of the graph of Fig. 2. Donnachie and Landshoff propose a pomeron-quark coupling of the Wu-Yang form

$$\beta_0 f(k_1^2)f(k_2^2)\bar{q}\gamma_\mu q\mathcal{P} \tag{6}$$

where k_1 and k_2 are the virtualities of the initial and final quark, and β_0 is a coupling with the dimension of an inverse mass. With the form factors $f(k^2)$ omitted, calculation of the contribution of Fig. 2 leads to a structure function proportional to $\beta_0^2 Q^2$, which clearly does not scale. Donnachie and Landshoff therefore argue that the form factors $f(k^2)$ should be included, and choose them phenomenologically, such that the cut off of the loop integral occurs at a hadronic scale Λ with $\Lambda = 0(1 GeV)$. This leads to a structure function proportional to $\beta_0^2\Lambda^2$, which scales, and is consistent with observation. With this motivation, they apply the same vertex to the calculation of Fig. 1. In this case, the form factor keeps k^2 close to the mass shell, so that the process can indeed be interpreted in the parton-model
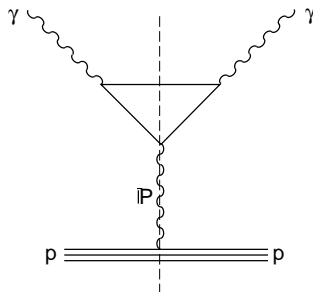
Figure 2: Quark-parton graph contributing to the inclusive diffractive cross section.

sense as a convolution of the photon-quark scattering cross section with the probability of finding a quark within the pomeron.

In our opinion, this is not the correct conclusion, for two reasons. The first is purely phenomenological, and relates to the experimental cuts imposed to define the diffractive events. Consider again the graph of Fig. 1, and consider the implication of imposing a pseudorapidity cut on the data, which in turn requires $\cos\theta \geq \cos\theta_{cm}^{\min}$. Clearly, this implies

$$k^2 \geq k_{min}^2 = \frac{M_X^2 + Q^2}{2}(1 - \cos\theta_{cm}^{\min}) \tag{7}$$

and forces the struck quark far off shell if $\cos\theta_{cm}^{\min} < 1$. A variety of experimental cuts have been employed in different experimental papers. In the first ZEUS paper, $\eta_{min} = 1.5$ [1], while in the second ZEUS paper $\eta_{min} = 2.5$ [2], and the $H1$ collaboration uses $\eta_{min} = 3.2$ [4]. In all cases, the events selected have an $x_{\mathcal{P}}$ dependence consistent with their interpretation as diffractive scattering events due to pomeron exchange with a trajectory $\alpha_{\mathcal{P}} \geq 1$.

In order to translate these cuts into a value for $\cos\theta_{cm}^{\min}$, and hence determine the constraint on the off-shell mass of the struck quark, we first note that η_{min} refers to the minimum pseudorapidity of all calorimeter clusters in an event, where a cluster is defined as an isolated set of adjacent cells with summed energy above $400 MeV$. The interpretation of η_{min} for the graph of Fig. 1 clearly requires some information how the jet associated with a final-state quark or antiquark develops. In jet studies at ZEUS, the cone radius $R = (\Delta\phi^2 + \Delta\eta^2)^{1/2}$ was set to one unit and gave results consistent with QCD expectations. A jet associated with a primary parton will spread in rapidity and, if we use the ZEUS algorithm, we may expect the spread to be of order 1/2 to 1 unit of rapidity. The numbers in Table 1 are derived using the smaller value of 1/2 for the spread in rapidity. A more detailed calculation requires a full Monte Carlo simulation using the detailed experimental cuts and will be sensitive to the details of the model used for the jet development.

If the diffractive events observed at HERA are due to the graph of Fig. 1, the lower bound on k^2 following from the experimental η_{min} cuts must be satisfied. These apply in the laboratory frame, and the boost from the laboratory to the centre-of-mass frame depends on the kinematic variables. In Table 1 we give the bounds k_{min}^2 for a range of these parameters and of η_{min} values used in the analysis of the experimental data[2]. The important point

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[2]The cuts listed are appropriate to the ZEUS data only. The H1 cuts are weaker, and correspond to very small k_{min}^2.

Q^2	β	x_P	$-k^2_{\min}\ GeV^2$ ($\eta_{\min} = 1.5$)	$-k^2_{\min}\ GeV^2$ ($\eta_{\min} = 2.2$)
10	0.175	.0032	3.1	0.4
		.0050	7.5	1.0
	0.375	.0020	0.9	0.12
		.0032	2.3	0.3
	0.65	.0013	0.2	0.03
		.0020	0.5	0.07
28	0.175	.005	7.5	1.0
		.0079	18.7	2.5
	0.375	.002	0.9	0.1
		.0079	14.2	1.9
	0.65	.0020	0.5	0.07
		.005	3.2	0.4
63	0.375	.005	5.7	0.8
		.0079	14.2	1.9
	0.65	.0032	1.3	0.2
		.0079	8.0	1.1

Table 1: Minimum virtuality of the struck quark following from a pseudorapidity cut.

to note is that, over significant ranges of these parameters, k^2 is constrained to be large, far from the hadronic mass scale needed to justify the interpretation of constituent partons within a pomeron structure function. It is impressive that the data obtained using these cuts requiring large k^2 have the same diffractive characteristics ($x_{\mathcal{P}}$ dependence, etc.) as those with weaker cuts. Given this we do not see how one can consistently interpret the rapidity gap events in terms of a mechanism which requires that k^2 be small.

The second reason for including high virtuality partons in calculating Fig 1 follows because a study of the perturbative (BFKL) pomeron [9] suggests that the form factor $f(k^2)$ does *not* cut off the integral at low k^2. Its general behaviour is illustrated by the two-gluon component, which yields diagrams of the type shown in Figs. 3 and 4 for the rapidity-gap and inclusive processes respectively. In both diagrams the momentum distribution of the two-gluon component of the pomeron should be cut off at the hadronic scale Λ. As a result, one may see in Fig 3 that there is an additional fermion propagator which will introduce a convergence factor at large quark virtuality, k^2. The same is true of the graph in Fig 4. Evaluating the amplitude squared of Fig 3 gives an additional term proportional to Λ^2/k^2 for large k^2, when compared to the determination of the amplitude squared following from Fig. 1 with a pointlike pomeron-quark coupling. Evaluating the amplitude squared of Fig 4 also gives a term proportional to Λ^2/k^2 for large k^2, when compared to that following from Fig. 2, again with a pointlike pomeron coupling. If one wishes to interpret this behaviour in terms of an effective quark-pomeron coupling we must choose $f(k^2)$ in eq 6 to be of the
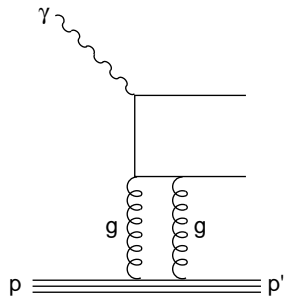
Figure 3: A two-gluon component of Fig. 1 contributing to the large-rapidity-gap diffractive scattering amplitude.
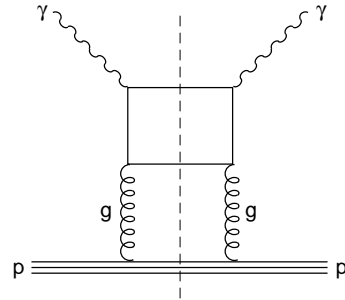
Figure 4: A two-gluon component of Fig. 2 contributing to the inclusive diffractive cross section.

form

$$f(k^2)^2 = \frac{\Delta^2}{(k_1^2 + k_2^2 + \Delta^2)} \tag{8}$$

This is to be compared with the choice of Donnachie and Landshoff [6] who identify the right hand side with $f(k^2)$. Our form is necessary if we are to avoid the problematic strong sensitivity to the pseudorapidity cuts just discussed. At first sight it might seem that the graph of Fig 3 should be re-interpreted as probing the *gluon* component of the pomeron with the gluon constrained to be near its mass shell. However, this is not the case, because of the constraint that there should be a rapidity gap between the proton and the final-state quark or anti-quark. This requires that the exchanged particle (the pomeron) be a colour singlet, so that the two-gluon component is the leading one, i.e., one cannot simply treat the second gluon as a spectator particle in the final state, as would be required for the gluon parton interpretation. The appearance of the Λ^2/k^2 factor is simply a reflection of the fact that the parton components of the pomeron are made of field components with dimension > 1. Of course, higher-dimension components will be more convergent, so the final form factor need not have the simple power behaviour shown in (8). Note that our approach differs from that of [10, 11] in that we do not *replace* the pomeron contribution with a two gluon component because the former is clearly a non-perturbative object. Our discussion of the two-gluon component was merely a guide to what it is reasonable to expect in the pomeron quark coupling.

4   Calculation of the Quark Contribution to Large Pseudorapidity Gap Diffractive Events

Although, as we have seen, the rapidity gap events measured at HERA do *not* directly probe the distribution of partons within the pomeron, the graph of Fig. 1 and the crossed graph may still be relevent provided one drops the assumption that the struck quark is close to its mass shell. In evaluating this graph, we continue to use the modified Wu-Yang form of

the quark-pomeron coupling of (8) discussed above. The calculation is straightforward, and leads to the following form:

$$\frac{dF_2^{D(3)}(\beta, Q^2, x_{\mathcal{P}})}{dt_{\mathcal{P}} d\Omega_{q\bar{q}}} = \beta_0^4 [F(t_{\mathcal{P}})]^2 \Lambda^2 (\frac{1}{x_{\mathcal{P}}})^{2\alpha_{\mathcal{P}}(t_{\mathcal{P}})-1}$$

$$((\frac{-t}{\Lambda^2})^{(\alpha_{\mathcal{P}}(t_{\mathcal{P}})-1)} f(t) + (\frac{-u}{\Lambda^2})^{(\alpha_{\mathcal{P}}(t_{\mathcal{P}})-1)} f(u))^2 \beta(1-\beta) \qquad (9)$$

where t and u are the usual invariants associated with the virtual-photon-pomeron sub-process, $F(t_{\mathcal{P}})$ is a combination of the Dirac elastic form factor of the proton and the quark [6], and $t_{\mathcal{P}}$ is the four-momentum squared of the virtual pomeron. Finally, integrating over the quark scattering angle and $t_{\mathcal{P}}$ gives

$$F_2^{D(3)}(\beta, Q^2, x_{\mathcal{P}}) \propto \beta(1-\beta)(\frac{Q^2}{\beta})^{\lambda} \qquad (10)$$

where we have taken

$$f(t)^2 (\frac{-t}{\Lambda^2})^{2(\alpha_{\mathcal{P}}-1)} \equiv (\frac{t}{\Lambda^2})^{\lambda-1} \qquad (11)$$

and $\alpha_{\mathcal{P}} \approx \alpha_{\mathcal{P}}(0)$. The most obvious change in the predicted form for the structure function, compared to the case where the partons are constrained to lie on mass-shell, is the appearance of a term potentially violating the scale invariance of the cross section. The origin of this term is immediate: since the energy of the quark-proton diffractive process is

$$s_{diff} = -\frac{k^2}{x_{\mathcal{P}}} = -\frac{Q^2}{\beta x_{\mathcal{P}}}(1 - \cos\theta_{cm}) \qquad (12)$$

there is a contribution to the diffractive sub-process amplitude proportional to

$$(\frac{Q^2}{\Lambda^2 \beta}(1 - \cos\theta_{cm}))^{1-\alpha_{\mathcal{P}}} f^2(\frac{Q^2}{\Lambda^2 \beta}(1 - \cos\theta_{cm})) \qquad (13)$$

If, as is suggested by our analysis of the ladder graphs, $k^2 f^2(k^2)$ is relatively slowly varying, we expect

$$F_2 \propto (\frac{Q^2}{\Lambda^2 \beta})^{\lambda} \qquad (14)$$

where

$$\lambda = 2(\alpha_{\mathcal{P}} - 1) \text{ if } f(k^2)^2 = \frac{1}{k^2} \qquad (15)$$

Let us consider whether eq(9) can describe the measured events. The overall power-law behaviour $(x_{\mathcal{P}})^{2\alpha_{\mathcal{P}}-1}$ follows from our Regge parametrisation of the amplitude for the diffractive sub-process, and is consistent with the experimental measurements, although ZEUS and H1 find somewhat different values of the exponent [4, 2, 3]:

$$\alpha_{\mathcal{P}} = 1.09 \pm 0.03 \pm 0.04 \quad H1$$
$$\alpha_{\mathcal{P}} = 1.15 \pm .04 \pm 0.04(0.07) \quad ZEUS2$$
$$\alpha_{\mathcal{P}} = 1.23 \pm 0.02 \pm 0.04 \quad ZEUS3 \qquad (16)$$

As may be seen from Table 1, different pseudo-rapidity cuts give rise to different constraints on $k^2_{\min}$. The new Zeus method for extracting the diffractive contribution does away with the need for such cuts at all and so will have no constraint on $k^2_{\min}$. Thus the various experimental methods probe different distributions of the virtuality of the struck quark. Given the form of our expression for the contribution of the graph of Fig. 1 it is possible that these differences may explain some of the discrepancies in the results found such as those in (16). However, it remains to be seen whether part of the apparent differences in (16) could be associated with the different types of event selection.

What about the β dependence at fixed Q^2? If we ignore the possible scaling violations, i.e., choose $\lambda = 1$, we predict a hard distribution $\propto \beta(1 - \beta)$. The observed form of the β distribution may be well described by the form [3]

$$(\frac{1}{x_\mathcal{P}})^a b(\beta(1 - \beta) + \frac{c}{2}(1 - \beta)^2) \tag{17}$$

with a, b and c constants: $c \approx 0.57$. Thus, (9) provides a reasonable description at large β, though it does fail to reproduce the rise seen at low β. The situation is somewhat ameliorated if one allows for non-zero values of λ. Taking $\lambda = 2(1 - \alpha_\mathcal{P})$, as would be appropriate to the choice $\tilde{f}(k^2) = 1/k^2$, with $\alpha_\mathcal{P}$ in the range given by the experimental measurements (16), generates an enhancement of low-β events, but this is still below the low-β growth observed. Thus, whilst there may be a component of the form presented above, it seems likely that an additional component may be needed. We shall consider shortly its possible origin.

The case of non-zero λ leads to a prediction of scaling violation, correlated with the β dependence just discussed. At present, the experimental situation is somewhat unclear, since H1 has found an indication of Q^2 dependence, whilst ZEUS does not. The H1 results are consistent with a growth with Q^2 of the structure function that is proportional to $\log_{10} Q^2$, with coefficients of proportionality (0.12 ± 0.09), (0.15 ± 0.09), (0.15 ± 0.09) and (0.17 ± 0.15) for $\beta = 0.65, 0.375, 0.175$ and 0.065 respectively. Interpreting these values in terms of λ gives a value of $\lambda = (0.07 \pm 0.05)$. Although not significant, this is of the correct sign to be interpreted as due to the term $\propto (\frac{Q^2}{\beta})^{2(\alpha_\mathcal{P}-1)}$ with $\alpha_\mathcal{P} > 1$ as is observed, and with a related enhancement of the structure function at low β as just discussed. However, with the measured value of $\alpha_\mathcal{P}$, the predicted λ will be too large, unless there is a suppression from the form factor $f(k^2)$ beyond that chosen in eq(15).

5 Summary and Conclusions

We have re-analysed the viability of the explanation of the diffractive events observed at HERA based on the quark diffractive scattering graph of Fig. 1. We have observed that the large *pseudorapidity* cuts favoured by early HERA analyses force the struck quark to be far off its mass shell. This means that quark diffractive scattering could explain a significant fraction of these data only if the struck quark could be far off shell without a significant suppression of the cross section. An immediate implication is that diffractive events selected in this way do *not* probe the structure function of the pomeron, at least in the normal sense of measuring the distribution of "on-shell" partons within a pomeron "target". Thus our

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intuition based on measurements of the structure functions of the nucleon in conventional deep-inelastic processes does not directly apply to the interpretation of the structure of the pomeron as revealed by large-pseudorapidity-gap events[3]. Our results are in conflict with the commonly-accepted form of the diffractive quark contributions calculated in [6]. We have calculated the full diagram of Fig. 1, allowing for a general form factor which does not cut the integral for the struck quark off close to mass shell. The resulting form gives a "hard" distribution which is modified by a term in which the β dependence is correlated with a scaling violation. While such a term may be able to explain the measurements of events at large β, it fails to reproduce the rise in the structure function seen at small β.
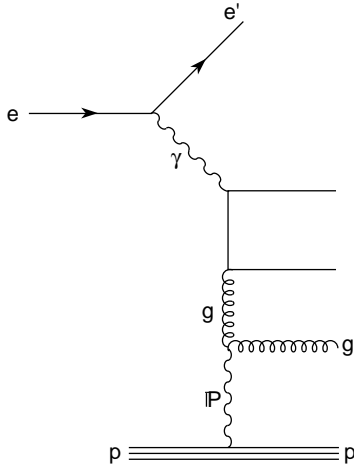

Figure 5: Diffractive gluon component of the pomeron.

The question immediately arises: what may the missing contribution be? An obvious candidate is the graph of Fig. 5, in which the pomeron couples to a gluonic component of the virtual photon. The reason this may be significant at low β is that graphs of this type have an infra-red singularity when the final-state gluon is soft, which leads to a $1/\beta$ contribution to the amplitude squared. This should be compared to the case of Fig. 1, in which the amplitude squared is constant for small β because there is no equivalent soft singularity. As a result, the graph in of Fig. 5 makes a contribution to the structure function which is constant at low β. Given that the pomeron may couple more strongly to gluons than to quarks, it is plausible that this graph may generate a significant contribution in the low β region. Together with the quark contribution this may provide a good description of the form of (17). This particular form was motivated by a two-gluon model for the pomeron investigated by Nikolaev and Zakharov [10]. However, we see that the essential feature, namely the absence of a fall-off at low β, does not rely on a two-gluon Lipatov-like interpretation for the pomeron, but simply reflects the characteristic infra-red behaviour associated with gluon emission, such as in Fig. 5.

Thus we arrive at a perfectly consistent picture of the large-*pseudorapidity*-gap HERA diffractive events, interpreted in terms of the diffractive scattering of (virtual) partons on

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[3]Note also that the much-discussed problems associated with implementing the momentum sum rule do not arise in our approach.

the proton. It will be particularly interesting if the Q^2 dependence of the large-β events can be extracted reliably, for there should be some scaling violation associated with the $(Q^2)^\lambda$ factors discussed above.

References

[1] ZEUS Collaboration, M. Derrick et al., Phys. Lett. B315 (1993) 481.

[2] ZEUS Collaboration, M. Derrick et al., Z. Phys. C68 (1995) 569.

[3] ZEUS Collaboration, M. Derrick et al, DESY preprint DESY-96-018 (1996).

[4] H1 Collaboration, T. Ahmed et al., Phys. Lett. B34 (1995) 681.

[5] G. Ingelman and P.Schlein, Phys. Lett. 152B (1985) 256; G. Ingelman and K. Janson-Prytz, Proc. Workshop "Physics at HERA", ed. W. Buchmüller and G. Ingelman, DESY 1992, Vol. 1, 233; G. Ingelman and K.Prytz, Z. Phys. C58 (1993) 285.

[6] A. Donnachie and P.V. Landshoff, Nucl. Phys. B267 (1986) 690; Phys. Lett. B185 (1987) 403; Phys. Lett. B191 (1987) 309; Nucl. Phys. B303 (1988) 634.

[7] J.D. Bjorken, SLAC preprint PUB-7096 (1996).

[8] W. Buchmüller and A. Hebecker, Phys. Lett. B355 (1995) 573.

[9] L.N. Lipatov, Sov. J. Nucl. Phys. 23 (1976) 338; E.A. Kuraev, L.N. Llipatov and V.S. Fadin, Sov. Phys. JETP 45 (1997) 199; Y.Y. Balitsky and l.N. Lipatov, Sov. J. Nucl. Phys. 28 (1978) 822.

[10] N.N. Nikolaev and B.G. Zakharov, Z. Phys. C53 (1992) 331; M. Genovese, N.N. Nikolaev and B.G. Zakharov, KFA-IKP(Th)-1994-37 and JETP 81(4) (1995) 625.

[11] P.V. Landshoff and O. Nachtmann, Z.Phys. C35(1987)405; M. Diehl, *Diffractive Production of Dijets at HERA*, hep-ph/9407399.